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Quarterly Progress Report

Division 6

15 December 1958

Digital Computer (U)

AFCRC-TN-58-1025

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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HEADQUARTERS
NORTH AMERICAN AEROSPACE DEFENSE COMMAND
PETERSON AIR FORCE BASE, COLORADO 80914-5001

REPLY TO ATTN OF J30S

26 NOV 1984

SUBJECT Classification Review "Quarterly Progress Reports"

TO ALFL (Lincoln Laboratory)

1. In response to ALFL letter, 28 Nov 83, the (11) confidential documents titled "Quarterly Progress Reports - Division 6 - Digital Computer" and dated 15 Jun 1954 through 15 Dec 1958 have been reviewed. Recommend the documents be declassified in whole since the sage system computer no longer exists and information contained in the documents no longer has an effect on national security.

2. To officially declassify these, documents, the 416L Security Classification Guide OPR, which is at HQ Sacramento Air Logistics Center, McClellan AFB, CA (MMCM), must be contacted with the recommendation to declassify.

JOHN E. MOORS, LCOL, CF
Ch, At Sensors Division

Memo for Record 14 Dec 84

Talked, by phone, with Ed Smalden, Sacramento ALC/MMCM, McClellan AFB, CA. Based on the recommendation in this letter he considers these documents declassified.

THOMAS J. ALPERT, MAJOR, USAF
CHIEF, ESD LINCOLN LABORATORY PROJECT OFC

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS ELECTRONIC SYSTEMS DIVISION (AFSC)
HANSCOM AIR FORCE BASE, MASSACHUSETTS 01731

REPLY TO ATTN OF: ALFL (Lincoln Laboratory) 17 Dec 84

SUBJECT: Declassification of Lincoln Laboratory Documents

TO: Mr. M. Wesley/A-109
Security Office
Lincoln Laboratory

1. Reference your letter of 17 Nov 1983 requesting declaassification and public release of MIT Lincoln Laboratory Quarterly Progress Reports issued between June 1952 and December 1958 (see atch 1).

The first major hurdle of this process has been cleared. Attachment 2 authorizes the declassification of the following documents:

"Quarterly Progress Reports - Division 6 - Digital Computer"

15 Jun 1954 (C)-(LL # 1, C315172C)
15 Sep 1954 (C) (LL # 1, C315189C)
15 Sep 1956 (C) (LL # 1, C315208C)
15 Mar 1957 (C) (LL # 1, C315206C)
15 Jun 1957 (C) (LL # 1, C315253C)
15 Sep 1957 (C) (LL # 1, C315254C)
15 Dec 1957 (C) (LL # 1, C315255C)
15 Mar 1958 (C) (LL # 1, C315256C)
15 Jun 1958 (C) (LL # 1, C315257C)
15 Sep 1958 (C) (LL # 1, C315258C)
15 Dec 1958 (C) (LL # 1, C315313C) 1721

The next major hurdle is obtaining public release. This will be done through ESD Public Affairs (Mr. John O'Brien).

ORIGINAL SIGNED BY

THOMAS J. ALPERT, Major, USAF
Chief, ESD Lincoln Laboratory Project Ofc

2 Atch
1. Lincoln Laboratory Ltr, 17 Nov 1983
2. NORAD Ltr, 26 Nov 84

Cy to: D. Murphy/B-107 w/atch
W. Hill/L-339 w/atch

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Quarterly Progress Report

Division 6

The Air Force Declassification Office concurs in the marked classification.
Date: 5-2-19 Reviewer: 137

Digital Computer (U)

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Issued 22 January 1960

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DIVISION 6 SUMMARY

In the Experimental SAGE Sector (ESS) 39 system tests were conducted, including ten shakedown tests using Models 2 and 3 of the direction center active (DCA) program. F-102A, F-101B, and F-104 interceptors were used at subsonic and supersonic speeds. The installation of the 65,000-register core memory was completed, and it was operated successfully with Model 3. The first airborne data processor for the airborne long range radar input (ALRI) system was assembled and the construction of a second one was started. The digital target detector and display were completed. A plan for deploying five ALRI stations in the Atlantic area and five in the Pacific was formulated. The guidance of IM-99A in SAGE was investigated: 27,000 simulated intercepts were run with the Bobcat simulation with nearly 100 per cent success against nonmaneuvering targets. Drafts of an IM-99B/SAGE integration plan, a SAGE guidance specification for the IM-99B, and an IM-99B weapons assignment function were completed. General systems test plans were prepared for SAGE/IM-99B and SAGE/FD (frequency diversity) radars. In continuing FD radar compatibility studies, design modifications were produced to provide the AN/FPS-6 and AN/FPS-20 with ECM capability. Criteria for the compatible collocation of FD radars and UHF ground equipment were set forth in TIR-1-276. The operation of the CHARM (CAA High Altitude Remote Monitor) system with live inputs began late in the quarter. The assembly of the TX-2 computer continued and the arithmetic element was operated with its final repertoire of instructions.

A study of SAGE height finding revealed that 3-D radars, such as the AN/FPS-27, can relieve height finders of routine height checks. The multiplexing of several gap filler outputs on a single phone line was considered an economical solution to the problem of Mode II gap filler coverage. A master SIF test plan was outlined: when combined with the NYADS "high density" tests, this plan will provide over-all beacon system tests for SAGE. A means of measuring Mark X collimation corrections automatically was initially successful.

This is the last Progress Report of Division 6, Lincoln Laboratory; it covers work performed during the period from 1 September to 31 December 1958. By 1 January 1959, virtually all Division 6 personnel except Groups 63 and 65 were in the employ of MITRE Corporation, a non-profit organization sponsored by Massachusetts Institute of Technology to perform research, development, engineering and advisory services to the United States Government, and initially to provide technical support to the Air Defense Systems Integration Division (ADSID) of the United States Air Force.

R.R. Everett
Division Head

J.F. Jacobs
Associate Division Head

31 December 1958

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SYSTEM DESIGN

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I. SYSTEM DESIGN
GROUP 61

A. SUMMARY

The investigation of IM-99A guidance in SAGE continued as simulated raid penetration tests were conducted to study the effect on intercept success of delaying launch until height information was received. More intercepts were successful when launch was delayed, but penetrations of a 100-mile circle described about the base increased. A summary of 27,000 simulated intercepts in the Bobcat (a SAGE non-real-time single-thread intercept by an IM-99A) tests was published. Nearly 100 per cent of the interceptions were successful against nonmaneuvering targets. Success against maneuvering targets varied with the time elapsed between completion of the target maneuver and the intercept attempt.

Drafts of an IM-99B integration plan in SAGE, a SAGE guidance specification, and an initial IM-99B weapons assignment function were completed. The integration plan outlines the design and status of the subsystems required for integration. The weapons assignment function draft describes changes necessary to provide a missile capability. BOMARC prelaunch control DCA program requirements were published, and a status report was completed on the IM-99B seeker interference problem. Pattern patrol, a tactic for the IM-99B, was described in a draft document, and a series of supplements is planned to describe improvements.

Changes were proposed in the operational specification for the 1960 SAGE system antiaircraft function. SABRE (SAGE battery routing equipment) assembly and testing began, and detailed planning for SAGE/SABRE testing was started. A SABRE working document was published, giving a project description and progress report.

In a study of tactics, data was gathered on the advantages of a tail-chase capability for the IM-99B using a non-real-time simulation programmed for the IBM 704 computer. Adding the tail-chase capability increased the potential range of the missile for intercepting nonmaneuvering targets behind the base.

Radio coverage checking procedures for manned interceptors were changed to conform to time-division data link (TDDL) control of the IM-99B.

B. BOMARC

1. IM-99A

Raid penetration tests using the SNORT/WGT (SAGE non-real-time/weapons guidance and tracking) simulation revealed that more intercepts were successful when missile launch was delayed until height information was received. Penetrations of the 100-mile circle increased, however, as a result of the delay. In this operating mode, the simulated intercepts stop at missile lock-on, the target is assumed to have been hit, and no other missiles are launched against it. To evaluate performance, counts are made of the number of targets which penetrate a circle about the missile base. In two cases, equivalent in all other respects, launching before height information was received wasted 56 missiles and nine targets penetrated the 100-mile circle; when launchings were delayed until height reports were received, all missiles locked on

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their targets but 38 targets came within 100 miles of the base. Increasing the DCA program subframe length from six to eight seconds to permit earlier height data insertion did not lower lock-on percentages. Another SNORT/WGT study showed that a 100-knot wind error perpendicular to the target flight path had little or no effect on missile accuracy.

All Bobcat tests were completed. The final report* summarized results of 27,000 simulated intercepts. Nearly 100 per cent of the interceptions were successful against nonmaneuvering targets flying at 300 to 1,000 knots at altitudes of 15,000 to 55,000 feet. Success against maneuvering targets depended on the time elapsed between completion of the target maneuver and the attempt to intercept. For a 600-knot target at 55,000 feet in a 30-degree maneuver at 1 degree per second, lock-on varied from 4 to 87 per cent as the elapsed time varied from 40 to 160 seconds. (A post-TRUD = 0 guidance command was later written into the simulation, and further work on logic changes improved the capability against maneuvering targets.) Other results: intercept success was greater for tail chase than beam or head-on approaches; target height errors between minus 5,000 and plus 10,000 feet did not seriously lower system performance; target radar and azimuth errors two to three times those expected in SAGE did not seriously impair system performance. The document recommends the fixed threshold method of controlling the rate of guidance. (This method resulted in an average of about 0.70 computations per 18-second frame.)

2. IM-99B

The group completed drafts of an integration plan for the BOMARC B in SAGE, a SAGE guidance specification, and an initial weapons assignment function. The integration plan indicates the design and status of the subsystems required for integrating the IM-99B in SAGE. It describes the work required to achieve the subsystem design and points up deficiencies in responsibilities and schedules for this work. Subsystem compatibility and system test requirements are also covered. The guidance proposal outlines a system of equations and logic for selecting profile and tactic and generating guidance commands for the IM-99B. It provides for three profiles and two tactics: cutoff (collision) and final turn cutoff. The intercept problem is solved by the same techniques to be used in the 1960 SAGE/manned interceptor system. The weapons assignment function draft lists changes necessary to provide a missile capability: (1) the combat center should be given the capability to dynamically allocate manned interceptors and IM-99Bs to itself and to the direction centers by switch action, (2) the combat center should be given the capability to commit manned interceptors and IM-99Bs against targets forwardtold from direction centers, (3) a capability should be provided to use manned interceptors and IM-99Bs against manually inserted ECM raids, and (4) a processing routine should be included to decrease the probability of interference among IM-99B target seekers.

BOMARC prelaunch control DCA program requirements were defined and published.† The document replaces an earlier draft and specifies in addition a 6-second minimum delay between

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*6M-5939, "Bobcat, A Simulation Study of the BOMARC A in a SAGE Environment," by R.B. Harvey, J. Dominitz, 4 November 1958.

†6M-5988, "IM-99B Prelaunch Control," by W.K. Rawdon, 19 December 1959.

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launchings to prevent overlapping of SIF returns from missiles in the same squadron. A revised burst number assignment method is also outlined.

A status report was completed on the IM-99B seeker interference problem. The report concludes that programming alone cannot provide an adequate, interference-free commitment rate. It recommends: (1) more flexibility in the stop command by reducing the missile's operating period in one-on-one assignment from two minutes to one, (2) changing the normal operating period in pattern patrol to a finite value, (3) studying the possibility of minor equipment changes — particularly to the antenna — to reduce the seeker's susceptibility to outside interference, and (4) introducing an ordered seeker channel-to-squadron pairing as part of the weapons assignment program.

Pattern patrol is described in a draft document, and a series of supplements is planned to describe improvements. In this tactic interceptors fly in formation on parallel courses with slightly overlapping areas of seeker coverage as they search through a volume of hostile concentration. It can be used effectively when electronic countermeasures prevent tracking individual aircraft, but azimuth information from jammed radars enables tracking of areas containing the jammers. Three stages are planned for the tactic. The first, or manual, is scheduled for the Model 8 DCA program (1 March 1961) and involves a minimum of change to the existing system. A transition stage would follow, with improvements added as they became operational. The final stage would include all elements needed to attain satisfactory ECM pattern patrol capability.

A draft specification for the BOPP (BOMARC pattern patrol) simulation was started. It is programmed for the IBM 704 computer. BOPP is designed to provide preliminary design verification of the pattern patrol technique of guiding IM-99Bs. Its guidance equations are compatible with those developed for the improved SAGE/manned interceptor system. The input to the simulation program consists of raid outlines generated by the SASTRO (SAGE strobe) program and is characteristic of data created by jamming raids. A data analysis program is an integral part of the simulation. The simulation will operate in non-real time, and the manual actions of direction center personnel will not be simulated.

C. ANTIAIRCRAFT INTEGRATION AND SIMULATION

Changes were proposed to the operational specification for 1960 SAGE system antiaircraft function* that would reflect on the integration of Hawk fire units. They include addition of Hawk fire units to the ATABE (automatic target battery evaluation) process. The ATABE concept, however, remains substantially unchanged from that in the original specification.

Block diagrams for the antiaircraft simulation were nearing completion, and a draft of the simulation objectives and methods was reviewed. The grid generation program was checked out and a copy was prepared for submission to the System Development Corporation.

1. SABRE

Assembly and testing of the breadboard experimental SABRE unit began after completion of the detailed logical design and circuit specification. Detailed planning for SAGE/SABRE testing

* 6M-5642, "Operational Specifications for Antiaircraft in the 1960 SAGE System," by L.B. Collins, et al., 1 August 1958.

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was started. The experimental unit is to be located at the Army air defense command post at Ft. Banks, Winthrop, Mass. and will be used in conjunction with the AN/FSQ-7 (XD-1) in the ESS direction center in Lexington. A SABRE working document* was published, giving a project description and progress report. SABRE will act as a transistorized, unmanned, inexpensive version of the missile master. It will integrate into the SAGE system those Nike-type battery complexes not equipped with missile master. SABRE consists of four 19-inch racks of solid-state equipment, including power, marginal checking, and integrated test facilities. It will:

(a) Receive AN/FSQ-7 (1,300 bit-per-second) ground-to-ground reference messages, select all batteries' binary-coded circuits, and transmit the message in the AN/TSQ-8 format and rate (750 bit-per-second) to all batteries.

(b) Receive AN/FSQ-7 designation messages, select the designated batteries' binary coded and battery data link circuits, and transmit the messages to the selected batteries.

(c) Transmit a dummy message (1,500 cycle-per-second tone) every 1.6 seconds over all binary-coded and battery data link circuits to all batteries to maintain the AN/TSQ-8 receiver's automatic gain control.

D. MODE II

A "double cross" method was proposed to achieve nonadjacent cross tell capability for Mode II operation. The proposal† would tie in cross tell data lines of nonadjacent sectors at sites not normally affected by emergencies at the direction centers. Two alternate proposals have been studied.‡ Both would use intermediate computers to interpret, process, and readdress cross tell messages, thus delaying the transmission. The "double cross" method calls for some interconnection of carrier equipment within commercial telephone central offices, located where possible, outside prime target areas. Two nonadjacent sectors, expanding their functions to take over those of a disabled sector, could fashion one or more complete paths through the cross tell network in Mode II where none existed in Mode I. Manual implementation of "double cross" would require additional equipment, consisting of short cable runs within the central offices and pulse reshaping equipment where necessary. Program adaptation would consist mainly of a proper address selection. Standard operating procedures would be established to help direction center and combat center personnel set up routes. Automatic switching equipment and advanced programs could further refine the operation.

E. WEAPONS ASSIGNMENT STUDIES

1. Manual Inputs

Representatives of Groups 61, 66, 67, and 68 formed a committee to investigate a proposal§ to replace the present manual inputs facility for weapons assignment with a low-data-rate system

* 6M-5923, "SABRE" by H.W. Boyd, 14 November 1959.

† To be published as TM-104, "Proposed Method for Nonadjacent Cross Tell," E.E. Hill, Jr.

‡ To be published as TM-105, "Nonadjacent Cross Tell in Mode II," E.E. Hill, Jr.

§ Draft 6M-5897, "Proposed Automatic, Low-Data-Rate Manual Inputs System," by S.B. Ginsburg, et al., 27 October 1958.

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for automatic entry into the AN/FSQ-7 and for feedback to external sites. The proposed input system consists of:

(a) Message composers for faster, more accurate message setup

(b) Existing teletype circuits for transmitting messages to the direction center from remote sites that have message composers

(c) Voice circuits for transmitting messages to the direction center from remote sites that lack message composers

(d) An automatic teletype input element that accepts incoming teletype signals from the message composers and automatically feeds them onto the manual input drums.

The proposed input system would replace at least three Air Force technicians per shift, two IBM 047 tape-to-card machines, four IBM 026 card printing machines, and three IBM 020 card readers. One, two, or three message composers, depending on the number of messages handled and the number of sources, would be installed in the direction center. Information telephoned to the direction center would be composed in message form in the manual inputs room and transmitted to the automatic teletype input element. There the messages would be assembled and transferred to the manual inputs drum field. The input element would be capable of accommodating up to 32 channels. The proposed input system does not preclude the possibility of a completely automatic manual input system. The committee agreed that the combat center should be considered a possible location for some of the manual input functions.

F. TACTICS STUDY

A quantitative study of the advantages of a tail-chase capability for the IM-99B was prepared. Data was gathered by BOCHK (BOMARC checking program), a non-real-time simulation programmed for the IBM 704 computer. BOCHK test runs showed that adding a tail-chase capability for three target speeds increased the potential number of kills. The increased potential varied with target speeds as follows: 28 per cent increase against 395-knot targets, 17 per cent against 515-knot targets, and 4 per cent against 1145-knot targets. Approaching targets, initiated at ranges from 0 to 200 nautical miles from the missile base line, were intercepted by the head-on and tail-on tactics at points differing at most by 15 nautical miles. This result indicates that, for this range interval, intercept success is almost independent of track-crossing angle. Further study was considered necessary to determine the usefulness and advantages of tail chase against maneuvering targets and in pattern patrol.

G. TIME-DIVISION DATA LINK

Radio coverage checking procedures for manned interceptors were changed* to conform to time-division data link (TDDL) control of the IM-99B. Additions to the direction center program included transmitter site selection, antenna selection, and message makeup. Transmitter site selection message assures transmission by a site whose coverage pattern includes the location

* 6M-5990, "Time-Division Data Link Control of Manned Interceptors and the IM-99B in SAGE," by W.C. Lee, 29 December 1958.

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of the addressed aircraft. In each program frame, each interceptor is paired with one of the 16 segments of the directional antenna or with an omnidirectional antenna at the selected site. Antenna selection routes messages to the omni antennas when the directional antenna is inoperative or true interceptor is overhead. Message makeup during each program frame, assembles the guidance data into the proper format for transmission to each interceptor, assigns to each message a burst number and output section, and updates data where necessary to compensate for delays in transmission.

H. MANNED INTERCEPTOR INTEGRATION

The F-108 was discussed in a mid-November meeting at North American. The following changes were included in its first employment plan:

(a) The combat center should have a commitment capability because of the aircraft's long range and high speed.

(b) After commitment the F-108 should be guided by the direction center in the sector where it is flying.

(c) If possible, the programmed UHF TDDL system should be used to communicate with the aircraft.

(d) Integrated control, which takes advantage of the interceptor's navigation system to reduce guidance errors, should be used when it is under SAGE control.

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ESS INSTALLATION

GROUP 62

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II. ESS INSTALLATION
GROUP 62

A. SUMMARY

The development of the ALRI (airborne long range radar input) system continued. The first airborne data processor has been assembled and will be installed in the Navy WV-2 aircraft in early 1959. Construction of a second airborne data processor, to be installed in the Air Force RC-121D aircraft, was started. The prototype digital target detector and display unit were completed. A 14-channel tape recorder for recording quantized radar data in the ALRI aircraft was completed.

The data link system between the ALRI aircraft and the South Truro AN/SRR-4 receiver station was tested, and reliable operation was obtained at ranges of 120 – 150 miles when the aircraft flew broadside to the receiver in a straight line without banking. A new YAGI antenna system was installed at South Truro and an AN/SRR-4 receiving system was installed on the roof of Lincoln Laboratory.

Development of UDAS programs continued: data link and radar programs were successfully operated. The drawings for SABRE logic were completed, and design of marginal checking and power supply portions continued.

B. ALRI

The design and construction of the airborne long range radar input (ALRI) system continued. ALRI will provide a seaward extension of SAGE radar coverage at both high and low altitudes. Significant progress is reported below in the following parts of the system: airborne data processors, digital target detector, display system, tape recording system, Mark X, and data link.

1. Airborne Data Processors (ADPs)

The assembly of ADP 1 was completed and checkout was started. ADP 1 is scheduled for installation in the Navy WV-2 (Planner 3) aircraft. A description of the joint Lockheed, NADU (Naval Air Development Unit), Lincoln Laboratory proposal of WV-2 modifications to outfit the aircraft for testing in the Phase I ALRI program can be found in 6M-5898.* The modification is broken down into three phases: removal and relocation of existing equipment, and installation of new equipment. Early in December, Planner 3 was sent to the Lockheed Air Service Corporation, Ontario, California, for the modifications. It is expected to be returned early in January 1959.

The design of ADP 2 was completed and the construction of the frame was started. This equipment is scheduled to be installed in the Air Force RC-121D aircraft No. 553 by 1 April 1959.

2. Digital Target Detector

The construction of the digital target detector (DTD) prototype was completed, and it was readied for final test and evaluation. This equipment was designed to receive and process ALRI radar data transmitted to the AN/FSQ-7 (XD-1) via phone line from the South Truro receiving station.

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* 6M-5898, "Specifications for the Modification to Planner 3 for the ALRI Program," C. J. Carter, 14 November 1958.

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The ferrite core memory was connected with the central machine, tested, and operated satisfactorily. All memory circuits were redesigned to reduce the number of special voltages required. The control panel was completed, tested, and connected to the central machine. A digital data transmitter and 1300-cycle oscillator were installed in the output system. A crystal, controlled clock oscillator, using germanium transistors, was designed and constructed for the DTD. It will drive up to ten inverter circuits with 3-volt 0.1-microsecond pulses with a repetition rate of 5.17504 mc, ±0.002%. Initial testing of the DTD with signals from an aircraft will begin in January.

3. Display

The display unit for the digital target detector was constructed, and initial checkout revealed no significant deficiencies. Live tests will start in January 1959.

The construction of the data processor display continued. The console was completed and checkout has started; the display logic is nearly complete. The power supplies have been modified to include the –10 volt supply for display and to include a separate 110V AC breaker for the display B+ voltages. It was determined that with the addition of one plug-in card in the subrack, the deflection system could be driven over 40 feet of twisted pair. The three subracks for display could then be in the frame with the computer and about 40 feet of cables to the display would be eliminated.

Modification of the Navy display console (so that it can be used as a mapper) continued.

4. Recording

In order to record the quantized radar video in the ALRI aircraft on magnetic tape, a 14-channel recording system has been developed and checked out. The tapes recorded on the airborne CEC (Consolidated Electrodynamics Corporation) model are played back on an Ampex S-3418 machine at Lincoln Laboratory.

The read amplifier-Schmitt combination which senses tape signals upon playback has been checked out on the Ampex recorder. Fourteen of these units were built for the ground environment recording system and are now operating. In addition, a higher gain version was built to monitor the low level playback of the airborne system.

5. Mark X (SIF)

Mark X SIF will be included in Phase I of the ALRI program as described in 6M-5891. The AN/APX-7 interrogator-receiver will be used, and Mode 1 will be used for interrogations. Interrogations will be at the same repetition rate as the search radar. Passive detection of the Mode 1 replies will be provided. The RC-121D aircraft will not be equipped for full SIF capabilities at this time, but present plans call for a manual backup facility to be provided about the time the airborne data processor is installed.

6. Data Link

The testing of the data link between the airborne radar platform (ARP) and the receiver station at South Truro continued.

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A single quantizer with an AN/ART-28 transmitter was installed on the Air Force RC-121D aircraft; a dual quantizer with an AN/ART-28 transmitter, on the Navy WV-2 aircraft. A new antenna system has been installed at South Truro, consisting of two stacked YAGI antennas used in a diversity system with two AN/SRR-4 receivers. The YAGIs with rotor drives were mounted on two 40-foot telephone poles, set approximately 89 wave lengths apart. The YAGIs have a beam width of approximately 30 degrees, which was increased to 55 degrees by slightly overlapping them. With ALRI aircraft 150 miles away, flying 15,000 to 17,000 feet and the AN/ART-28 transmitter putting out an average power of 20 watts, the data link signals were received with no difficulty by the new antenna system. Reliable communication, however, was obtained at this range only when the aircraft flew broadside to the receiver and did not bank. Recordings of r-f signal level studies showed that a single conventional omnitype aircraft antenna is not adequate for ALRI operation at the transmitted power levels employed. Preliminary tests of a dual diversity system revealed a number of problems to be solved before satisfactory data transmission can be made while the ARP is turning.

A new receiving system has been installed at Lincoln Laboratory. This equipment consists of an AN/SRR-4 receiver, the data decoding equipment, noise analysis equipment, and a YAGI-type antenna using an AR 1 Radiart rotor unit.

C. TDDL TESTS

To determine the performance of the TDDL ground environment, tests were performed which measured the ability of the subsystem to process valid messages and to reject invalid messages. The tests performed from 3 June to 30 September 1958 are described in 2G-25-14, "Interim Report on Time-Division Data Link Subsystem Testing" (J. E. O'Brien, Group 25, G. E. Masters, IBM, R. W. Olsen, BTL, and J. R. Currier, 4 November 1958). One purpose of the tests was to establish a system error rate, and this was based on "good message tests" only. The calculated error rate, on this basis, was .0684% or 1 message rejection out of 1,462 messages or 1 message rejection every 439 seconds. The tests used the RCA time-division multiplexing equipment, an automatic communications system capable of processing computer-generated messages and transmitting these messages to manned interceptors or missiles at a rate of $33\frac{1}{3}$ messages per second. The AN/GKA-5 multiplexer group accepted ground-derived digital data information from the AN/FSQ-7 (XD-1) computer, and the message was transmitted to the flight control groups via the Bell A-1 data service.

No AN/GKA-5 multiplexer errors were observed during all the valid message acceptance ground equipment tests. A dual site test was run to check the site circuitry of the multiplexer. A parity rejection test was performed to check the parity rejection features of the AN/GKA-5 multiplexers. The data turned out to be too erratic because the total messages received by the AN/GKA-5 group did not agree with the total messages sent by XD-1. These tests will be rerun in January. Four live flight tests were flown, using two F-86 aircraft from Bedford Air Force Base. During the first test, the aircraft did not receive any messages transmitted by the AN/GKA-5 group at South Truro; the succeeding two tests were run successfully from both the Lexington Field Station and South Truro; the fourth test was called off after the first leg because

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of computer failure. RCA engineers and technicians have been conducting extensive tests on all phases of the present AN/GKA-5 ground equipment groups and the AN/ARR-48 airborne equipment groups at the Lexington Field Station.

The TDDL subsystem test program has been rewritten to operate in the 65,000-register core memory, to be compatible with modifications to the TDDL equipment in the F-86-L, and to consolidate its many features. It is now being checked out.

D. UDAS

UDAS (utility diagnostic active system) programs have been developed to detect system failures while operating in real time with the DCA (direction center active) program. This quarter, the Model 2B DCA program was successfully cycled with the UDC (control) and the teletype output programs. The FTI (data link trouble indicator) and RRR (radar registration) programs were successfully operated; the RRR was run on 12 September with data from Ampex tape, and the registration checked out with processed correlation history results from the same day. An operating height message monitor program has been completed, and the necessary minor changes for operation with the 65,000-register core memory are being made. The above tests demonstrated that diagnostic programs could feasibly be operated in real time with the DCA program without interfering with air defense functions. However it was concluded that the implementation of UDAS-type programs posed significant difficulties, in that they would have to be modified and adapted to each model of the DCA program as it was produced.

E. SABRE

An experimental model of SABRE (SAGE battery routing equipment) is being constructed at Lincoln Laboratory and will undergo design shakedown and compatibility tests. The role of SABRE is to facilitate the automated integration of non-missile master equipped Nike-type battery complexes into the SAGE-controlled continental air defense system.

Group 62's tasks for SABRE are planned as follows: (1) construction, (2) test design provisions, (3) testing, (4) maintenance and documentation, and (5) prototype responsibility. The logic drawings have been completed with plug-in unit pin connections included. The design of the marginal checking and DC power supply package continued: it will contain simple bridge rectifiers with constant voltage line regulation. A setup for testing the transistor pluggable units has been constructed and is ready for use.

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DIGITAL COMPUTER DEVELOPMENT

GROUP 63

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III. DIGITAL COMPUTER DEVELOPMENT
GROUP 63

A. SUMMARY

The TX-2 computer is in a second phase of assembly and operation; it now operates with its arithmetic element and part of its final repertoire of instructions checked out. At the end of the next phase, summer of 1959, the TX-2 complex (central machine, terminal equipment, and service programs) will be ready for wider applications. The preparation or modification of the following terminal equipment was in process: the input-output "Lincoln Writer" system, a Xerographic printer, a Soroban high-speed punch, and a magnetic tape transport.

Further work on the small magnetic-film memory for TX-2 suggests the replacement of the driving core-matrix switch by a diode-matrix design expected to result in faster operation and reduced noise currents on unselected lines.

Some progress has been made in measuring and reducing the skew of the magnetization axes of evaporated-film spots.

B. TX-2

Early in the quarter, the Phase I operation of TX-2 was completed; the necessary experience in programming a multiple sequence computer was obtained to make possible the optimization of the details of the instruction code and to gain more familiarity with the organization of terminal equipment control. TX-2 was then shut down for four weeks in order to make the desired modifications. Emphasis for the remainder of the quarter shifted to completion of the arithmetic-element control.

The modifications to the instruction code were checked out, and the arithmetic element and its control were completed. In addition, four of the arithmetic-element instructions were checked out at low speed. These are: (1) Tally (count the number of "ones" in the accumulator), (2) Cycle A (ring shift the accumulator), (3) Scale A (arithmetic shift the accumulator), and (4) Normalize A (like "scale factor" on WW I). Because of the configuration control (the ability to split the arithmetic element into subgroups of nine bits), there are 64 variations of each instruction.

When the arithmetic element is fully checked out, Phase II of TX-2 assembly will be complete, and (except for the small experimental magnetic-film memory and the 4,096-word transistor-driven core memory), it will be ready for operation using a photoelectric paper-tape reader, a paper-tape punch, and a cathode ray tube display for its input and output.

Phase III of TX-2 assembly and operation will start early in 1959 and will probably last about three months. The goal for this phase will be the installation of sufficient terminal equipment, the development of an adequate base of test and utility programs, and a level of operating reliability such that serious applications work may commence.

C. TERMINAL EQUIPMENT

The TX-2 input-output writer and its control are nearing completion. This interim unit is an on-line typewriter which will serve until the Lincoln Writer system is completed. It features

a special type face designed for computer use and a platen-shift mechanism to give superscripts and subscripts.

Preliminary discussions have been held with representatives of Stromberg-Carlson who will be asked to design a new character-forming stencil for the Charactron tube in the high-speed Xerographic printer in order that it have characters like those on the typewriter.

The Soroban high-speed (200 lines/sec) paper-tape punch has been modified for transistor drive. After extensive study its performance appears to be very satisfactory. The design of the control logic for the paper-tape punch and tapes continued.

A redesign of the magnetic tape transport is in progress which will increase its capacity from 10-inch to 14-inch reels, will reduce "cross-talk" between channels by the use of $\frac{3}{4}$-inch tape to allow larger head spacings than the $\frac{1}{2}$-inch tape, and will reduce the physical size of each transport to a depth of about six inches through the use of flat "pancake" style driving motors.

D. MAGNETIC-FILM ENGINEERING

1. Low Frequency Hysteresis Looper

It has been found that placing the integrator of the film hysteresis looper after the amplifier attenuates the high frequency noise which is often generated in the amplifier. The limit on the size of film that can be looped is now determined by low frequency components due to distortion in the drive current rather than by high frequency noise.

2. Plated Films

Experiments indicate that plating on thinner gold substrates produces films with lower values of H_k. Further reduction of the gold substrate may provide extremely thin plated magnetic films without disastrously high values of H_k.

3. Film Memory for TX-2

The insertion of a diode in the secondary winding of each of the switch cores supplying transverse excitation provides two improvements in circuit operation of the memory. The rectifying action of the diode eliminates the second current pulse from the switch core, and thus allows a shorter cycle time; diode nonlinearity severely attenuates the small noise current on each transverse line which previously caused a slow deterioration of information.

The use of the diodes suggests the elimination of the core matrix switch with its attendant wiring problems, and the construction, in its place, of a diode matrix to perform the complete switching function for the transverse lines. The design of such a switch is being investigated.

The preliminary drawings of logic and physical layout for the magnetic film configuration memory are completed.

4. Fabrication Techniques

A moving substrate has been installed which makes it possible to deposit six 16 × 16 arrays in each run as it passes successively over an aperture the size of one array. The resulting skew

appears to be always less than ±2 degrees as compared to as high as 15 degrees with the stationary large-area evaporation. An automatic motor drive for the moving substrate is being designed.

Samples of fine-line etched wiring, in dimensions suitable for film memories, have been requested from Sanders Associates, Nashua, N.H. and Photocolor Corp., Schenectady, N.Y. The Lincoln Laboratory wiring shop has also demonstrated ability to do work of this type. Sanders Associates has been requested to quote on a 256-register package utilizing their "flexprint" wiring. A compromise 256-register package, designed for construction in the Laboratory, will have etched wiring, lugs, and some hand wiring.

5. Pulse Testing

Experiments have been performed to measure the error introduced in pulse measurements of skew. Flux from adjacent spots introduces the error: an increase in the apparent skew of a spot surrounded by others skewed in the same direction is observed. A new pickup-head is being designed.

ESS SHAKEDOWN TESTING

GROUP 64

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IV. ESS SHAKEDOWN TESTING
GROUP 64

A. SUMMARY

Thirty-nine tests were conducted in the Experimental SAGE Sector (ESS) including 16 for shakedown, two for evaluation, and 13 for operator training. F-102A, F-101B, and F-104 interceptors were employed in the live tests at subsonic and supersonic speeds. Model 3 of the DCA (direction center active) program was used in live tests and found compatible with large memory, whose installation was completed. Major deficiencies on Model 3 were found only in the intercept direction function.

In special studies, a means of measuring Mark X collimation corrections automatically was initially successful. A redesign of the present manual inputs system was proposed to make it more automatic and more reliable.

General system test plans were prepared for SAGE/BOMARC B and SAGE/FD radars. Members of Group 64 at the Montgomery Air Defense Sector continued the design of SAGE/BOMARC A tests.

B. SHAKEDOWN

Group 64 conducts tests in ESS for system shakedown, system evaluation, and operator training. In shakedown, the current version of the DCA program is examined, deficiencies are uncovered, modifications are made, and satisfactory system operation is sought. In support of shakedown, the group reduces data recordings, analyzes data resulting from the tests, and undertakes studies of certain program functions.

Thirty-nine tests were conducted in ESS during the quarter: 16 were for shakedown (13 using live aircraft), two were for system evaluation (both using live aircraft), 13 were for operator training (three using live aircraft), and eight were special tests mainly to examine particular program functions (two using live aircraft). F-102A, F-101B, and F-104 interceptors at subsonic and supersonic speeds were employed in the live tests. ESS operations were suspended for four weeks beginning on 10 October to complete the installation of the 65,000-register core memory. Texas Tower 2 was under the control of the Boston Air Defense Sector and was not used in ESS tests.

1. DCA Program

At the beginning of the quarter, Model 2 of the DCA program was used in system tests, principally for operator training exercises. Meanwhile preshakedown testing of Model 3 DCA program continued. Errors found in Model 3 included those in training and battle simulation, height finding, and intercept direction. Group 64 brought these errors to the attention of SDC and assisted in correcting the program. Live shakedown tests using Model 3 began on 25 September and continued throughout the quarter, except during the installation of the large memory in October. In December the ESS version of Model 3 was replaced by a production model. Tests with both versions verified that Model 3 is completely compatible with the large memory, and

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that no major deficiencies in program functions exist except for the following in intercept direction: erroneous indications of foldback and impossible intercept conditions, errors in nose cone sensing logic, and the failure of lead pursuit guidance commands to cause rapid convergence of interceptor and target.

2. Special Studies

a. Mark X Collimation

A means of measuring Mark X collimation corrections automatically was tried with encouraging results. A new data reduction program was written to analyze the tape produced by the EPSCOM single track tracking program. The resulting collimation figures were produced more rapidly and without the element of human error.

b. Manual Inputs System

To resolve weaknesses in the present manual inputs system, a study group proposed its redesign as follows:

(1) Message composers in the manual inputs room and at the source should employ the selective correction feature and include a typewriter keyboard.

(2) An automatic transmission service-teletype should be introduced.

(3) An automatic low-data-rate input element (ALDRI) should be used.

(4) A method of indicating computer acceptance or rejection to the source should be incorporated; if a rejection occurs because of an error in the data, an indication of the item or field in error should be made available to the source operator.

(5) The number of the DCA program safe data tables should be increased to include the manual inputs information necessary for adequate startover.

C. SYSTEM TEST PLANS

General system test plans have been prepared for SAGE/BOMARC B and for SAGE/FD radars. Plans are being made for ESS tests with ALRI, ATABE, SABRE, CCM, F-106, and the Model 5 program.

The SAGE/BOMARC A test team at the Montgomery Air Defense Sector continued its test designing. Preliminary data from tests of the Model 3 program operating with live radars indicated that basic surveillance functions operated successfully. Testing and analysis will continue.

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VACUUM TUBES

GROUP 65

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V. VACUUM TUBES
GROUP 65

A. SUMMARY

The average life of the Stromberg-Carlson Charactrons and the Machlett Laboratories Scriptrons is now about 5000 hours in AN/FSQ-7(XD-1) consoles. Because of a high cathode rejection rate at the time of manufacture, major cathode improvement programs were initiated by both companies this quarter. The Hughes and Machlett Typotrons, incorporating new write-time specifications, have had satisfactory storage and erasure characteristics with no early life failures.

Improvements were made by Hughes Aircraft in their 21-inch controlled-persistence display tubes in cathode uniformity, writing gun alignment, and storage and collector mesh alignment. Ten five-inch Tonotrons have shown less than 10% degradation of storage surface after 4300 hours of electron bombardment on Group 65 life racks. A program was started to encapsulate the persistron display panels to preserve their characteristics during vacuum treatment; glass encapsulment was initially successful.

Tests of the cylindrical ceramic window of the Eimac X-626 Klystron to determine the cause of dielectric breakdown continued. Results indicate that a uniform conductive coating on the ceramic effectively reduces arcing and corona.

B. DISPLAY

1. Situation-Display Tubes

Although the average life of Charactrons in AN/FSQ-7(XD-1) consoles has been about 5000 hours for the past 2 years, the realization rate at time of manufacture has varied considerably because of poor cathodes. When the rejection rate reached 25% this quarter, major cathode improvement programs were initiated at both Machlett Laboratories and Stromberg-Carlson to obtain optimum performance of the oxide cathode.

Westinghouse, under contract to IBM, plans to conduct a two-phase program to:

(1) Investigate the processing of present Charactron cathodes, and test other presently available, but expensive, cathode systems;

(2) Develop the Honeywell nickel matrix cathode which has been under investigation at Westinghouse for two years. This cathode has demonstrated life in excess of 5000 hours in production kinescope tubes, but is not easily reproducible.

Barium-nickel cathodes made by Lincoln Laboratory, a British firm, and Superior Electronics were put into cathode ray tubes by Superior Electronics, and life tests on them will be performed at the Barta Building.

2. Typotrons

The Typotrons now being produced at Hughes Aircraft to the new increased write-time specifications have had satisfactory storage and erasure characteristics with no early life failures.

The Typotrons being produced at Machlett to the same specifications have been satisfactory except that they have not been storing uniformly at the edge of the quality circle. Tests indicate that these tubes have a poorer vacuum than the Hughes tubes. Machlett has undertaken a careful review of all their processing procedures.

C. RESEARCH

1. Controlled-Persistence Tube

Hughes Aircraft is improving the 21-inch controlled-persistence display tube developed by them for IBM. The first tube evaluated by IBM in June had a viewing screen of P22 green phosphor and a sandwich-type storage target of magnesium fluoride and potassium chloride. Because the bright green color of the P22 phosphor was unsatisfactory in the application of this tube, P4 phosphor was used in later models. The potassium chloride in the storage sandwich picked up contaminants during processing. A more stable dielectric was obtained by substituting sodium fluoride in subsequent models.

The second tube (with the proposed improvements) was operationally tested in a display console at DC-2 (Syracuse). The storage mesh developed small wrinkles during the vacuum bake cycles causing lack of uniformity in the display. The display and operation of this model on the $2\frac{1}{2}$ second display cycle were not as satisfactory as in the Charactron. The characters were less well defined, and overpainting was more of a problem because the characters were larger. Future tests were recommended at 5, $7\frac{1}{2}$, and 10-second display cycles to find a better utilization of this model's capabilities.

The third tube, still at Hughes, shows improvements in cathode uniformity, writing gun alignment, and storage and collector mesh alignment (24° in respect to each other). The fifth and sixth models will have a mesh of lines across the solid characters to reduce space-charge aberrations at the matrix. The use of 150 storage mesh will permit smaller characters.

2. Tonotron Life Test

The magnesium fluoride type of storage surface in ten 5-inch Tonotrons has been under electron bombardment for 4300 hours on the Group 65 life test racks. There has been less than 10% degradation of the storage surface.

3. Solid-State Display Devices

The design, construction and evaluation of persistron display panels in cathode ray tubes continued. Persistron panels are optical memory panels in which each cell exhibits steady emission for a controlled period followed by a sharp fadeout without external switching. The program is confined to the triggering of persistron panels by a cathodoluminescent phosphor in a cathode ray tube.

A series of 2 × 2-inch persistron panels was mounted in cathode ray tubes which, in turn, were enclosed in three-inch cylindrical tubes. The objective of these experiments was to study the panels in vacuum ambients and under electron bombardment. Sylvania furnished the electroluminescent layers; Group 26 prepared the photoconductor and the webbing for optical isolation.

The presently available persistron cannot be given the regular cathode ray tube vacuum bakeout that is necessary for the oxide cathode processing without altering the photoconductors. Special long low-temperature vacuum bakeouts also changed the photoconductor in the persistron panels. The persistron action could not be restored completely by later oxidizing the surface and further vacuum pumping. The oxide cathodes in unbaked persistron cathode ray tubes can be kept activated by removing the water moisture and persistron contaminants continuously with a titanium getter ion pump incorporated with each tube. Although the oxide cathodes in all of the persistron tubes have activated poorly, six tubes have been operating on life test from 1000 to 4300 hours with adequate cathode current.

An active program was initiated to encapsulate the persistron panels so that their characteristics were not lost during vacuum treatment. One three-inch cathode ray tube with an araldite encapsulated panel has had 2500 hours of satisfactory vacuum life. Further attempts to use araldite, mylar, mica, and other low temperature encapsulating techniques were not successful in the cathode ray tube. A program to develop glass encapsulment of persistron layers (for the vacuum treatment and to free oxide cathodes from persistron contaminant) has been initially successful. This required glazing temperatures that are almost comparable to the sintering temperatures of the photoconductor. If the photoconductor has been processed properly, it may take the heat cycle necessary for the glass encapsulment. The development of a satisfactory glass embedment technique depends on bringing vacuum-tight electrodes out of the glazed surface.

4. Eimac X-626 Klystron Tests

Further testing of the cylindrical ceramic window of the Eimac X-626 Klystron was carried on in the high voltage bombardment chamber constructed at the Barta Building for this purpose. Under d.c. conditions at 100 KV, test cylinders were bombarded with electrons to determine the cause of dielectric breakdown. Results of the tests indicate that a uniform conductive coating, either on the inside or the outside of the cylinder, effectively reduces arcing and corona.

A negative charge that accumulates on the inside of the ceramic cylinder is considered to be one reason for dielectric breakdown. A more important cause of breakdown is thought to be stress across the wall of the ceramic, which reaches a maximum when arcing occurs. Other factors may contribute to the breakdown: impurities or imperfections in the ceramic material could cause weak points; field emission at metal to ceramic junctions might be the source of a component of current that would contribute to cylinder charging.

Two basic types of conductive coatings were tested on both the inside and outside of the cylinder: a low resistance helical coating and a high resistance continuous coating. Both types reduced arcing and corona. However, if the coating was not uniform, or if the electron beam was concentrated on a portion of the coating, the local heating caused the cylinder to crack under stress. It was concluded that a uniform conductive coating that does not change during tube fabrication or under electron bombardment would solve the problem of dielectric breakdown in the tube.

SPECIAL STUDIES

GROUP 66

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VI. SPECIAL STUDIES
GROUP 66

A. SUMMARY

CHARM system operation with live radar and flight plan inputs began in mid-December. These operations, tests, and demonstrations were held twice weekly for three-hour periods.

B. CHARM SYSTEM

CHARM (CAA High Altitude Remote Monitor), an experimental system, was designed to demonstrate and evaluate the ability of a SAGE-like surveillance system to assist the Federal Aviation Agency (FAA, formerly CAA) en route air traffic control system, especially at high altitudes.* Beginning in mid-December, flight plans, position reports, and other air movements data were fed into the Whirlwind I computer at the Barta Building from the Boston Air Route Traffic Control Center (ARTCC). The computer processed the information, combined it with data gathered by search radars at Bath, Maine, and South Truro, Massachusetts, and displayed the composite situation to flight plan track monitors. The monitors used the displays to correlate and correct flight plan positions.

C. OPERATIONS

Initial operations were devoted primarily to demonstrating CHARM to visitors from industry and government agencies. This testing revealed that flight plan data was not always readily obtainable from ARTCC personnel who were otherwise occupied in the actual control of air traffic. Plans are, therefore, being made to allow CHARM operating personnel to monitor radio communications between the ARTCC high altitude sector and aircraft and immediately feed the data into the computer.

*A summary description of CHARM will be found in Quarterly Progress Report, Division 6, Lincoln Laboratory, M.I.T. (15 September 1958) Sec. VI.

ADVANCE SAGE PROGRAM DEVELOPMENT

GROUP 67

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RUNDQUIST, H. I.
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VII. ADVANCE SAGE PROGRAM DEVELOPMENT
GROUP 67

A. SUMMARY

The study of FD (frequency diversity) radar compatibility problems was continued: a detailed analysis of antijamming techniques produced design modifications which are expected to provide the AN/FPS-6 and AN/FPS-20 with ECM capability. SAGE tracking studies resulted in an improved method of eliminating dead hostile tracks from the system. The SAGE Tracking Group concluded that a single optimum set of parameters for all tracking situations does not exist. The decision to employ either heavy or light smoothing constants will be based on the anticipated quality of radar environment.

ALRI (airborne long range radar input) system deployment problems were anticipated and solutions prepared. A plan was formulated for maintaining five stations in the Atlantic area and five in the Pacific: it was estimated that final ALRI units could be integrated within the continental air defense system by early 1961.

Mark X (SIF) interlace ratio techniques of alternating different mode interrogations with each main radar transmitter pulse were investigated. A three-to-one interlace ratio of Mode III to Mode II, with a detection threshold value of 12, promised adequate beacon performance for either civil or military aircraft in SAGE. A master SIF test plan was outlined. When combined with the series of "high density" tests in New York, this plan will provide the over-all beacon system tests for SAGE. The SAGE/Mark XII Integration Study Group formulated a plan for the addition of a true cryptographic mode (Mode IV) to the existing three Mark X (SIF) modes.

A detailed study of the semiautomatic height finding system in SAGE revealed that 3-D radars, such as the AN/FPS-27, can relieve height finder radars of routine height checks. A new priority and special request scheme was added to the miscellaneous height finding program. The addition of a gap filler multiplexer at a long range radar site was considered an economical solution to the present problem of Mode II gap filler coverage. Several gap filler outputs can now be multiplexed onto a single phone line for transmission to a direction center.

Dual tracking requirements in terms of increased storage and frame operating time were analyzed: the total drum storage increase for the three programs involved is 48 per cent over the DCA program (Package D System) without dual tracking. In the 1959 system, additional input-output transfer time will be .012 seconds.

Preliminary man-machine analysis indicates that certain functions performed by direction center supervisory personnel can be relocated to operational personnel. Track monitors, for example, can take over drop and reinitiate actions currently performed by tracking supervisors.

B. ADVANCE AIR SURVEILLANCE DESIGN

1. FD Radar/SAGE Compatibility

A committee continued to study the compatibility of the FD family of radars with the SAGE system. The objective of this study is to determine necessary changes and additions to FD radars and associated equipment. Design modifications are being prepared to provide the AN/FPS-6 and AN/FPS-20 with ECM capability.

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A detailed analysis of antijamming techniques produced the following conclusions:

(a) Beamwidths of strobes should be narrow for strobe returns (one-way antenna patterns).

(b) Two-stacked antenna beams offer advantages over a single beam.

(c) Pulse-to-pulse frequency jumping can be successfully compromised with an adequate MTI.

(d) Pulse compression is useful when transmitter peak power is limited.

(e) Diplexing and duplexing equipment will improve the quality of radar data.

(f) Staggered PRF will prevent lower blind speeds for relatively low frequency radars.

(g) Numerous antijam fixes are available for simultaneous operation in a single radar receiver.

(h) Undesired point targets such as birds can best be removed by using an x^2 characteristic of voltage versus time.

(i) A fast time constant can remove long video pulses that might saturate limiting amplifiers.

(j) AN/FST-2 quantizers are individually compatible with any of the antijam fixes in the receivers.

2. Tracking Studies

An improved method of eliminating dead hostile tracks from the system was developed. A program will detect kill insertions at weapons consoles or kill insertions entering the computer from AA batteries. When a kill report reduces a target flight size to zero (unknown), the track will be distinguished from a track with no reported flight size. The track with a zero flight size will be identified as a tentative kill. As a result, the weapons assignment program or the ATABE (automatic target battery evaluation) program will not be required to assign new batteries to the track. The tentative kill track will then be examined by the tracking review program to determine whether the track is actually dead. If the track is not dead, the tentative kill tag will be removed, and the track may be considered for commitment to the weapons assignment or ATABE programs. If the track is dead, the track will be referred by an attention device to the track monitor and tracking supervisor consoles.

The SAGE Tracking Group concluded that a single optimum set of parameters for all tracking situations does not exist. Efforts were made to perfect SAGE tracking by manipulation of tracking parameters and the introduction of relatively minor logic changes utilizing the newly developed TDG (track data generation) and TNA (tracking and analysis) programs. Track data was generated for a maximum sample of 100 instances of a specific tracking situation. Independent tracking and statistical analysis of each case in the sample enabled selection of the best parameters for turns, straight-line, and crossing data trail situations. The decision to use either heavy or light smoothing constants ultimately requires an operational judgment based on the desired type of tracking and the anticipated quality of the radar environment. For example, the light (A-87) smoothing constant has a low maximum speed error and performs well on 80 degree turns, but ranks somewhat below the heavier (1.5, 1.5) smoothing constant on the 20, 40, 60 degree weave. As a result, A-87 parameters should be selected for vigorous maneuvers.

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3. SAGE ALRI System

ALRI (airborne long range radar input) system deployment problems were anticipated and solutions prepared. It was estimated that the final ALRI units could be integrated within the continental air defense system by early 1961. Approximately 70 aircraft are currently available for ALRI use. A plan to maintain five stations in the Atlantic area and five in the Pacific area was prepared. Flying at 15,000 feet in race-track patterns, the aircraft will remain within line-of-sight of a long range radar and within 80 per cent line-of-sight of ground data link receiving stations.

Several new switch actions will be required at the direction center. When radar tracking or navigator-aided tracking is unavailable, or when radar ECM activity is strong, the computer will employ autonomous tracking which requires only position and velocity data from the aircraft's autonavigator. The ALRI program will receive height information from a modified APS-45 radar aboard the RC-121D. If the Mark XII identification system is available for ALRI installation, a manual method of operation will be used. The deployment of ALRI systems provides significant Mode II capability, since the data from a single airborne radar platform will be available to several direction centers. ALRI will provide strobe information to the SAGE system as part of a comprehensive CCM operation.

4. Mark X (SIF) and Mark XII

Interlace ratio techniques of alternating different mode interrogations for each main radar transmitter pulse were investigated, and the effect of a one-to-one interlace ratio setting of Mode III and Mode II interrogations at joint use sites on target detection and azimuth alignment was determined. This ratio setting involves "target splits" and the problem of detecting Mode III targets; it would result in a universally unsatisfactory beacon performance. Depending upon the parameters used, either a large azimuth error would be introduced for civil targets or a serious target detection deficiency would result. In contrast, a three-to-one interlace ratio of Mode III to Mode II with a detection threshold of 12 provided the most desirable operating parameters and promised adequate beacon performance for either civil or military aircraft in SAGE. To verify this evaluation, experimental tests will be conducted.

A master SIF test plan was outlined. When combined with the series of "high density" tests being conducted in New York, this plan will provide the over-all beacon system tests for SAGE. The Mark X SIF test plan will:

(a) Establish a satisfactory configuration for SAGE radar beacon site equipment,

(b) Determine parameter settings for the AN/FST-2,

(c) Verify the findings of SAGE Mark X operation procedures listed in 6M-5482*,

(d) Select the operational option which minimizes interference, and

(e) Establish the adequacy of SIF tracking logic for SAGE.

*6M-5482, "System Office Proposal: SOER #264, Separation of Mark X Tracks," by E.S. Pulk, IBM, 24 February 1958.

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These test objectives will be pursued in a five-fold testing program at the ESS, MOADS, NYADS and Burrough Paoli test sites. Test Program 1 will decide the best equipment configuration, including sidelobe suppression for SAGE. Test Program 2 will establish the optimum parameter settings for the AN/FST-2. In Test Program 3, beacon system tests in a high-density environment will be conducted. In Program 4, BOMARC tracking with the Mark X SIF beacon tracking system will be tested. Test Program 5 will provide for SAGE system testing.

The SAGE/Mark XII Integration Study Group continued its evaluation of the Mark XII subsystem. A true cryptographic mode (Mode IV) will be added to the three modes of the existing Mark X (SIF) beacon system. Significant equipment changes include a crypto-computer on the ground interrogator and a similar unit in the aircraft transponder. The security of the code key is determined by the number of possible code key settings (approximately 10^{23}), the number of possible interrogations (2^{32}), and the complexity of the encipherment logic. The National Security Agency has judged that a code key setting is secure for approximately 72 hours. Mode IV code key settings will be changed every 24 hours.

5. Height Finders and Gap Filler Multiplexer

A detailed study of the semiautomatic height finding system in SAGE revealed that height returns are most accurate and the number of negative and false replies fewest when target ranges are between 20 and 100 miles. 3-D search radars such as the AN/FPS-27 can relieve height finder radars of routine height checks. In this system, the height finder radars would not be eliminated, but would provide accurate height data at critical times; e.g., when a track is initiated and immediately before interception. A number of program changes were introduced to improve the height finding function, including a new priority and special request scheme in the miscellaneous height finding program.

The addition of a gap filler multiplexer at a long range radar site was considered an economical solution to the problem of Mode II gap filler coverage. In the present system each gap filler operates as a separate entity until gap filler data reaches the AN/FSQ-7 input drums. As a result, there are individual circuits from each gap filler to its direction center. If gap fillers are to be used in Mode II, they must be cross-tied to adjacent direction centers. Phone lines, as well as input channels and possibly direction center mapping equipment, would have to be duplicated. For these reasons, the present Mode II Operational Specification (6M-5264-1) omits Mode II gap filler coverage.

Since the gap filler data rate does not require the capacity of one phone line per gap filler, several gap filler outputs could be multiplexed onto a single phone line. Slowed-down video data from all gap fillers would be routed to a long range radar site where the data would be mapped and multiplexed for transmission to a direction center.

C. SURVEILLANCE DEVELOPMENT AND TESTING

1. Dual Tracking

The increased table storage and frame time required for dual tracking logic currently operational in an experimental version of the DCA program (Package D System) was estimated. The

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addition of dual tracking has affected three programs: correlation (TCO), smooth and trouble detection for established tracks (TSE), and smooth and predict (TSA). Dual tracking requires a 52 per cent increase in drum storage for the TCO program, 82 per cent for the TSA program, and 34 per cent for the TSE program. The total increase for all three programs is 48 per cent over the drum storage required for the same DCA version without dual tracking. Dual tracking logic allows two duals to be carried for each track in the system. Each dual requires three registers of table storage so that total table storage allotted for dual tracking is six times the track capacity. If spare drum storage is not available (as was true of Model 2), the additional storage would be seven times track capacity. Program operation time reflects increases of 15 per cent (200 frames) for TCO, 73 per cent for TSA, and 17.5 per cent for TSE. Input-output transfer time between drums and memory would increase .157 seconds for a 100-track 1957 system. In the 1959 system, the additional input-output time is .012 seconds for any track capacity.

D. ESS SUPPORT

1. Man-Machine Studies

Operator tasks in SAGE direction center tracking sections were analyzed in detail. The present study is a sequel to the functional diagramming of the tracking group,* it is concerned with time-costing the sequence of actions and decisions of tracking personnel in order to increase tracking capability for the 1960 SAGE system. Task relocation and programming improvements are expected to be the result. Preliminary analysis indicates that certain functions performed by supervisory personnel can be assigned to operators. Tracking supervisors, for example, perform many drop and reinitiate actions that could be assigned to track monitors. Such a transfer of function is significant in the light of statistical data derived from ESS station logs. Reinitiate actions consume fifty per cent of the tracking supervisor's actions. Likewise, seventy per cent of the time devoted to relatively routine decisions by the tracking officer is used in dropping extrapolated HUKP (hostile, unknown, known, or pending) tracks. During normal operations, the tracking supervisor could assume this function.

The new dual track program is expected to decrease track monitor activity. An analysis of the dual track program shows that dual tracking reduces the number of "lost" tracks by 20 per cent.

* Quarterly Progress Report, Division 6, Lincoln Laboratory, M.I.T. (15 September 1958) Sec.VII, D.2.

SYSTEM OFFICE

GROUP 68

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VIII. SYSTEM OFFICE
GROUP 68

A. SUMMARY

The System Office released 15 Technical Information Releases (TIRs): among the most significant was TIR 1-276, which set forth siting criteria for compatible collocation of frequency diversity radar and UHF ground equipment. 6M-5983 predicts the requirements of ESS users for planning purposes. In nine meetings the SAGE Problem Committee obtained Lincoln/ADSID concurrence on 47 System Office Recommendations. Forty-eight IBM specifications were reviewed for approval and/or concurrence.

B. SYSTEM OFFICE RELEASES

Recognition of the requirements for siting criteria to achieve compatible collocation of frequency diversity radar and ultra high frequency ground communication equipment resulted in the release by TIR 1-276 of the following:

(a) Lincoln Laboratory Memorandum 6M-5967, 8 December 1958, and 6M-5967 Correction #1, 10 December 1958, "Siting Criteria for Compatible Collocation of UHF Frequency Diversity Radars AN/FPS-24 or AN/FPS-35 and UHF Ground Communication Equipment."

(b) Lincoln Laboratory Drawings No. S-8873-3, "Ground-Air Transmitter-Receiver Site – Land, Building, and Antenna Layout," and No. S-8873-5, "Ground-Air Transmitter-Receiver Site – Alternate Siting Configurations."

(c) Lincoln Laboratory Group Report 2G-25-11 Revision 1, "Consideration of Mutual Interference between Frequency Diversity (FD) Radars and SAGE Communication Equipment," 4 December 1958.

Other documents released by TIR by the System Office and the Production Coordination Office in the September-December 1958 period were:

Document	Subject	TIR
6M-5762	Mark X Selective Identification Feature	1-258
2M-0184	Subsystem Acceptance Tests	1-260
S-26-8 S-27-13 S-50-15 S-51-31 S-52-7	IBM Equipment Specifications, Switching Facilities to Connect Standby Computers to Output Channels	1-262
6M-5770	SAGE Display Consoles	1-264
6M-5678	SAGE Height Addressing Capability	1-265
6M-5793	SAGE/BOMARC A Prelaunch Simulator	1-266
6M-4893-3, C1, C2	DCA Program Changes for BOMARC A Guidance, Output Message Makeup and Weapon Assignment	1-267

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Document	Subject	TIR
2G-25-5 2G-25-8 2G-25-9	Automatic Substituting and Transmitter Receiver Alarm System	1-268
6M-5915	Manual Data Inputs, Equipment and Procedures	1-269
6M-5927	Master Reference List, AN/FSQ-7 and AN/FSQ-8 Equipment Specifications	1-270
MF8-412-3114-1	BTL Memo, Retrofit Test Philosophy	1-271
G-281165	Missile Master Crosstell Subsystem	1-272
6M-5408-1	1960 SAGE System, AA Function	1-273
76-3	LL Group Report on CW-396A Rigid Radomes	1-274
C-9127	LL Drawing SAGE Operations Room at Radar Sites	1-275

The System Office issued 6M-5983, "ESS Utilization Plans for 1959" (R.S. Fallows, J. Giordano, H.S. Hayes, Capt. R.B. Mollo) 11 December 1958. This document predicts user requirements (amount and type) in ESS for planning purposes and will be revised by the System Office as changes occur. The report includes:

(a) A listing and description of the proposed features for ESS
(b) Miscellaneous features which will improve ESS operations
(c) A list of facilities required to incorporate these features
(d) A list of required XD-1 channels
(e) Additional subsystem test requirements
(f) Summary of XD-1 computer time requirements
(g) Compilation of additional amount of ESS computer programming support
(h) Conclusion and recommendations.

C. SYSTEM OFFICE RECOMMENDATIONS

The SAGE Problem Committee met nine times and obtained Lincoln/ADSID concurrence on 47 System Office Recommendations. Among the more significant are the following:

SOER 368 ESS Experimental Missile Master Communications

This recommendation was written in connection with an experimental ATABE (automatic target battery evaluation) feature in ESS. Additional facilities were recommended in order to conduct this ESS/missile master test.

SOER 361 Safety Control for SAGE Missile Operation

Requirements for maximum safety in SAGE/BOMARC testing and operation have been established. This change to the DCA program was recommended to meet these requirements.

SOER 116 Manual Input Studies. Redesign of Flight Plan Card Format

The burden of computing the position of a flight plan formerly carried by the AMIS and ID operators was shifted to the computer by this recommendation. At the same time, a new flight plan format was recommended.

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SOER 376 Track Count on Height Summary DID

A criterion for the height supervisor in selecting time delays and in estimating height finder time utilization is the total number of tracks in the system. To improve this as an indicator, it was recommended that only established or correlating crosstell noninterceptor and nonsimulated tracks be included in the number displayed in the height summary DID.

SOER 369 Automatic Clearing of Console Switch Panels

The necessity of manually clearing unwanted switch depressions before making new insertions and the absence of any direct immediate indication that the inserted information had been accepted by the computer placed unsatisfactory limits on the speed and accuracy of operator switch insertion proficiency. To remove these limits, this recommendation suggested that a switch give the operator the capability of selecting normal, nonautomatic operation and that circuits be provided to automatically clear all switch modules with certain exceptions. It was further recommended that this equipment change be evaluated in ESS for possible application to SAGE.

SOER 397 Nonduplicated SAGE Console Functions AN/FSQ-8

Some capabilities of the senior air surveillance officer console are not duplicated at any other console. Since such capabilities would be lost should the SASO console fail, it was recommended that these nonduplicated capabilities be added to certain other consoles in SAGE combat centers.

D. IBM SPECIFICATIONS

Lincoln/IBM concurrence was obtained on 27 IBM specifications pertaining to the AN/FSQ-7 and AN/FSQ-8. In addition, 21 similar specifications were rewritten, approved, and awaiting concurrence.

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ADMINISTRATION AND SERVICES

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IX. ADMINISTRATION AND SERVICES
GROUP 60

A. SUMMARY

The activity of Group 60 is mainly of a supporting nature. The General Engineering Section furnishes design, fabrication, and assembly services, principally to the physics and computer sections of Group 63. The activities of the joint card- and tape-processing facilities and the maintenance of Whirlwind I are reported below.

B. CARD- AND TAPE-PROCESSING FACILITY

The joint facility to process computer materials for the users of AN/FSQ-7 (XD-1) and the IBM 704 reports 6.1 million cards processed and 1,031 hours of line printer usage. In the support of SAGE and ESS, 34.6 per cent of the card processing was for direct support, 52.7 per cent was for advance development, and 12.7 per cent was for maintenance and training. Research and administrative groups were the other principal users.

C. WHIRLWIND I

The average reliability of the Whirlwind I computer, including input-output equipment, was as follows:

Per cent good time	97.2
Mean free time (hours)	35.5
Total assigned hours	1,486.4
Average lost time per interrupting incident (hours)	0.6

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